FUNDAMENTAL PRINCIPLES IN RADAR SPEED MEASUREMENTS

an operators manual

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Pub: # 16,249- 51- 2000- 03/28/90 C.R.
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INTRODUCTION

Before we embark on the actual training, we ought to consider some questions that have been asked by many motorists (and police officers, and judges) in recent times: Just how good is RADAR? Is it accurate? Can we trust it? Or, as some have claimed, is RADAR liable to "clock" trees at 85M.P.H., houses at 25 - 30 M.P.H., and law abiding motorists at all kinds of false speeds ? What are the facts ?

The basic fact is that more people and more attention is being paid in court to RADAR instruments and the people who operate them. RADAR always has and probably will continue to come under attack in court. Some of these attacks have proven successful: one of the best known, recent challenges to RADAR occurred in Dade County, Florida, early in 1979, and resulted in the rejection of RADAR evidence in 80 pending speeding cases. Similar successful challenges have happened elsewhere, and others undoubtedly will happen in the future. Does this mean that RADAR instruments are simply no good ?

Quite the contrary: unbiased, scientific tests consistently have shown that the RADAR instruments used in traffic enforcement are reliable and effective tools when carefully installed and properly maintained.

Then WHY do we hear of all these successful challenges to RADAR in Court ?

The really significant fact is that RADAR is only a tool. Manufacturers could design and build a RADAR that is as accurate and reliable as anything that was ever made, and that would not add one iota to the capability, skill, or expertise of the people who use the RADAR. Does RADAR make mistakes ? Generally and practically speaking, No. Do RADAR operators make mistakes ? Unfortunately, Yes ! And some of them make many mistakes, and make them often.

The fact is that human error has been the root of almost all successful challenges to RADAR. The Dade County incident is a good case in point: contrary to wide-spread belief, the challengers in Florida did not prove that RADARs will "detect 85 mph trees or 28 mph houses or cars travelling faster than they actually were. What they did show was that, if certain basic operating procedures are violated, those kinds of absurd speed measurements can appear to occur. In other words, if the operator either doesn't know what he's doing or simply doesn't care, he can foul up in such a way that the

"evidence" which his RADAR produces will be worthless.

There is a logical explanation for each one of the absurd speed measurements that were cited in Dade County. They will be discussed and explained later in this course. The most significant fact to come out of Dade County was not that RADAR was unreliable, because that isn't true. Rather that so many operators, not just in Florida but everywhere, haven't been properly trained to use these instruments and thus be able to avoid absurd readings and indications. From a training viewpoint, it is obvious that a person cannot become a competent RADAR operator simply by reading a brochure, or by watching a short film, or by listening to a half-hour's "overview" of instruction, or just by working with it on the job with little or no prior preparation. Speed enforcement based on RADAR is NOT difficult to learn; however, it can be complex without sufficient training. The courts and defense attorneys are aware of this and consequently are demanding more and more evidence that the RADAR operator has had proper training and experience: they want to know that YOU know what you are doing when you use that tool.

So, finally, just how good is RADAR ? It is only as good as YOU, the operator. If you put your best effort into this course, you'll have all the knowledge you need to become a very good RADAR operator, and when you gain experience in the field you shouldn't develop bad habits or sloppy procedures that cause many problems. Take full advantage of the training you are about to receive. Get as much out of it as you can. Then, you'll never have to worry about 85 mph trees.

SPEED OFFENSES AND SPEED ENFORCEMENT

1. Speed in Society

Since the earliest days of the automobile, speed has been its most controversial feature. Motor vehicle manufacturers have continued to develop vehicles with speed potential to meet and exceed practically any requirement. A major selling point for some automobile manufacturers has been the handling capabilities of their products at high speeds. These manufacturers have had little trouble in finding a market for these new and faster products. It seems that the public has always exhibited a desire for new and faster automobiles.

The Supreme Court of Pennsylvania said:

> It is only necessary to resort to the most cursory observation to find the evidence that many drivers of automobiles in their desire to put their novel and rapid machines to a test of their capacity, drive such vehicles through the streets with a reckless disregard for the rights of others. (1)

The preceeding statement was made in 1906 in upholding a conviction for speeding in excess of 7 mph in violation of the city ordinance. This preoccupation with speed seems to be even more prevalent today within our highly mechanized society. It seems the faster we can get anywhere, the better. People rush to work and rush to play. The automobile provides the means to maintain this harried existence. For some, it also serves as a means to relieve tensions. These individuals turn their automobiles into weapons, tools of aggression. They take out their frustrations on the highways by pushing the gas pedal to the floor and through aggressive driving.

This is not to say that everyone driving an automobile is obsessed with speed nor is it a condemnation of high speed travel. High speed vehicles and highways are, at times, necessary to the efficient flow of traffic. We must not, however, lose sight of the inherent dangers in high speed travel. Increased speeds affect these three elements of driving:

a. The OPERATOR, increased speeds serve to tax the basic capacities of the driver, such as reaction time (the time required to respond to a situation) as well as amplifying any existing deficiencies, such as vision.

b. The VEHICLE, increased speeds tax the automobiles equipment, i.e. the Brakes, suspension, steering, etc.

c. Road SURFACE, increased speeds amplify the potential hazards of any deficiencies in the road surface, i.e. potholes, construction etc., or situational conditions resulting from weather, ice, snow, rain

Increased speeds interacting with one or more of these elements can result in an accident. To grasp the dramatic impact speed has on these elements, let's examine a simple task, such as stopping a vehicle. This simple task incorporates the three elements above and is, therefore, greatly affected by increased speeds.

Let us suppose that the average reaction time is 3/4 of a second. Our average motorist is proceeding along a typical road. The roadway is smooth and clear. He's driving along at 20 mph and notices a hazard ahead. He reacts to this hazard in 3/4 of a second. At 20 mph his car moves 22 feet during 3/4 of a second. Assuming, further, that his brakes are in proper working order, it will require an additional 20 feet of braking distance to bring his vehicle to a complete stop. In total it has taken 42 feet to stop the car. Now, let's suppose that our driver was proceeding at 40 mph. Reacting to a hazard within the same reaction time span, his car will have travelled 44 feet before he begins to brake. It will take an additional 81 feet to bring the vehicle to a complete stop; for a total stopping distance of 125 feet. Remember, at 20 mph his braking distance was only 20 feet. However, the braking distance at 40 mph is NOT twice the distance required at 20 mph, but 4 TIMES. Further, at 80 mph it would be more than 16 TIMES the distance required to stop at 20 mph. See Figure 2 - 1.

Technical advancements can continue to alter the mechanics of an automobile or improve the design of roadways to allow for greater speeds, but as we've

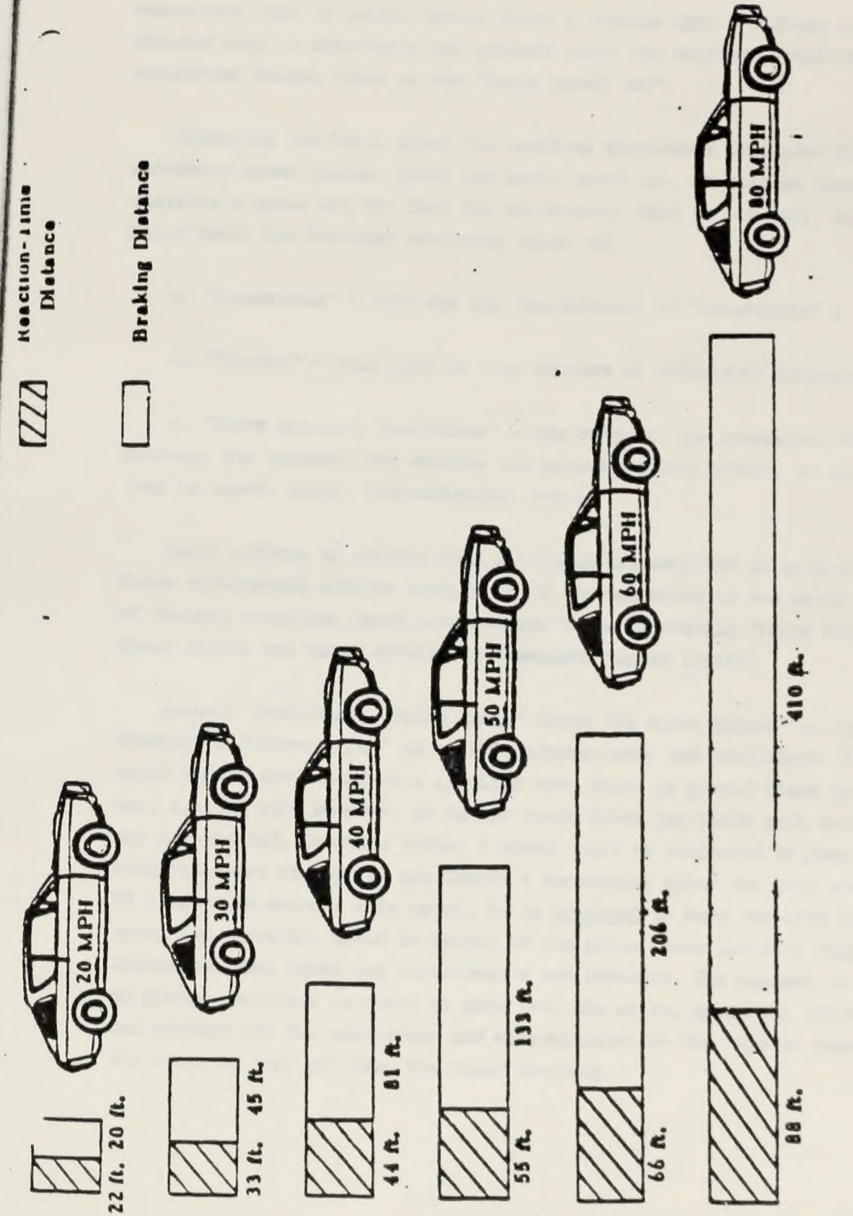

Figure 2-1. Distance Required to Bring Vehicle to Complete Stop

seen in the example above, these are just two of the factors involved. There remains the human element which we cannot redesign. What is required, then, is stricter control of the driver. Increased enforcement efforts are required to assure that drivers maintain a safe and reasonable speed, and to encourage voluntary compliance with the speed limit. Enforcement activity be considered a process of educating the motorist into voluntary compliance with traffic laws. This educational process is most often achieved by creating an awareness of the consequences of violating traffic laws. Enforcement measures may be considered repressive, in some cases, in that they aim to deter potential violators by making apprehension and certain punishment an unpleasant experience.

In effect, traffic law enforcement is a conditioning process whereby, the individuals themselves, or through the experiences of friends or acquaintances, learn that violating traffic laws leads to an unpleasant experience (fine, jail, loss of license, etc.), and therefore, the mere symbol of authority or possibility of detection and apprehension, results in a safer and more alert driver who will be spared a more unpleasant experience from a traffic collision.

2. A Short History of Speed Regulation

As the problem of speed has been with us throughout the years, so has the problem of controlling speed. Various types of legislation to control speed have been introduced throughout our country's history. The primary purpose of this speed regulation has not been to restrict the flow of traffic, or hassle drivers, but to make traffic movement efficient with minimum danger to people and property.

According to Joseph Nathan's Famous Firsts, the very first traffic law in America was passed in New Amsterdam, now known as New York, on June 12, 1652; it prohibited the riding of horses at a gallop, or driving a vehicle at galloping speed, within the city limits.

As the number of automobiles increased, so did the body of laws governing their use. This volume of statutes and ordinances was based upon a basic

assumption that no person should drive a vehicle upon a highway at a speed greater than is reasonable and prudent under the existing conditions. This assumption became known as the "basic speed law".

Enforcing the basic speed law involves procedures different from enforcing speed limits. Under the basic speed law, it must be shown that the violator's speed was too fast for conditions. This is not easy, since any basic speed law includes ambiguous terms as:

a. "Reasonable" - what are the determinants of "reasonable" ?

b. "Prudent" - this word is also subject to individual interpretation

c. "Under existing conditions" - can refer to the conditions of the roadway, the weather, the vehicle (in proper working order), or the operator (was he sober, tired, inexperienced, etc.).

Early efforts to enforce this ambiguous law resulted in some confusion. These enforcement efforts brought about the emergence of two major schools of thought regarding speed enforcement: those advocating "Prima Facie" speed limits and those advocating "Absolute" speed limits.

Loosely translated, "Prima Facie" means "at first glance" or "in the absence of further proof" as to the circumstances and conditions. Prima facie speed limits are stated as a specific rate which is posted along the roadway: i.e. 35 mph. However, it is the basic speed law which must be enforced and adjudicated. In other words, a speed limit is indicated to make the motorist aware of what is considered a reasonable speed for that area. If a motorist exceeds this speed, he is presumed to have violated the basic speed law. However, speed in excess of the prima facie limit is only an indication that speed was unreasonable and improper. The accused is entitled to produce evidence in court to show that his or her speed was reasonable and prudent for the conditions and circumstances at the time in question; the court or jury provides the final decision.

"Absolute" speed limits are based on laws which simply prohibit driving faster than a specified numeric speed. This school of thought insists that the "basic speed law," alone, leaves too much room for individual interpretation by motorists, many of whom aren't reliable enough to make correct decisions as to appropriate speeds. They also maintain that prima facie limits are practically unenforceable, since questions arise in almost every case as to rate of speed in respect to environmental conditions and what a reasonable speed for those conditions really is. With absolute limits all drivers exceeding these limits have simply violated the absolute speed law. When the law prescribes a definite numeric maximum limit, driving in excess of the limit, regardless of conditions, is a violation. The only proof required is that the motorist exceeded the limit. Circumstances and conditions have no bearing on the driver's guilt or innocence. They are not regarded as elements of the offense and are immaterial insofar as guilt is concerned.

In the early versions of the Uniform Vehicle Code prima facie limits were recommended and a substantial majority of states adopted the prima facie speed provisions. Meanwhile, the absolute type of law fell into disfavor. Some states had a combination of the two. That is, (1) a basic speed law with prima facie limits, and (2) an absolute maximum beyond which it was unlawful to drive under any circumstances. Several states still use prima facie limits in designated speed zones but with an absolute maximum on the open highway.

a. Relationship between Speed and Safety

When the 55 mph speed limit was enacted, its sole purpose was to save fuel, and help reduce our dependence on foreign fuel sources. At the end of 1974 a more important effect of the reduced speed limit was noticed: Traffic fatalities had been reduced by 8,856.

An analysis of speed data shown in Figure 2-4 indicates yearly increases in speeds reaching a high point in 1973, and dropping down sharply with the passage of the 55 mph speed limit in 1974. Figure 2-5 (on the previous page, with Figure 2-4) indicates yearly traffic fatalities. Compare the two graphs for a moment. They appear almost identical to one another. Wherever speeds have increased significantly,

Figure 2-4* Average Free Moving Vehicle Speed on Main Rural Roads in the U.S. 1957-1977

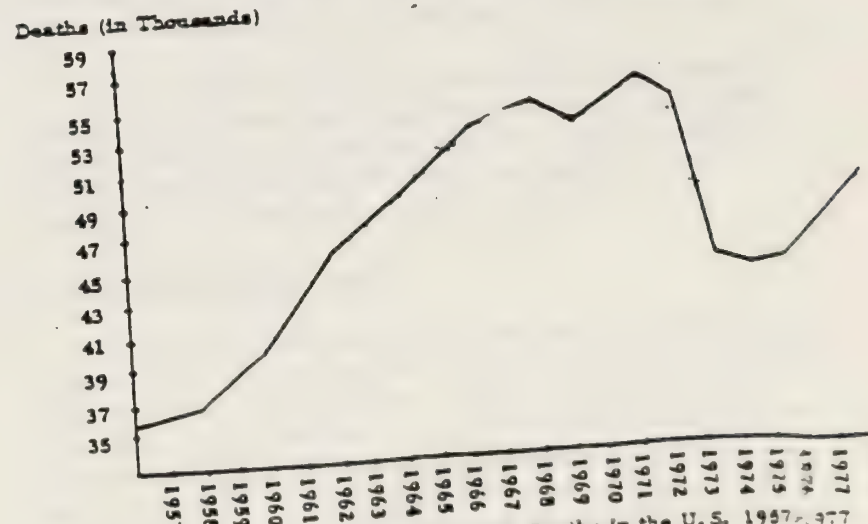

Figure 2-5. Reported Motor Vehicle Deaths in the U.S. 1957-1977

*Data based on 55 MPH Fact Book, U.S. Department of Transportation, September 1978.

so have fatalities; and conversely wherever speeds decreased, so did fatalities. In fact, in 1974, the first year of the 55 mph limit, traffic fatalities decreased 16.2%: the largest annual absolute* fatality reduced since 1942.

At first glance you might guess that these dramatic reductions in fatalities were simply a result of a reduction in travel during the fuel shortage: the less travel time, the less chance of being in an accident. To disprove this assumption, we would have to look at the number of fatalities reported as a function of the number of miles actually travelled. The "Fatality Rate" provides such a measure. The fatality rate measures the number of fatalities per 100 million miles travelled. Since the early seventies the fatality rate had been declining by about 3% a year, because of better engineering and other safety factors, such as increased use of seat belts. However, the fatality rate plunged from 4.2 in 1973 to 3.6 in 1974. This represented a very significant decrease of 14% ! Obviously, reduced speed seems to have saved lives.

Not only has the 55 mph speed limit reduced the number of fatalities, it has also reduced the number of significant injuries. The reported number of spinal cord injuries caused by auto accidents has dropped as much as 60 to 70% in some areas of the country. In all, disabling injuries resulting from traffic accidents dropped 10% after 1973 when two million people were severely injured.

It should come as no great surprise that speed has such a tremendous effect on fatality and accident severity rates. As we discussed earlier, increased speeds tax the operating limitations of both the vehicle and the driver. Speeding increases the stress on tires, steering and braking systems, and also amplifies driver limitations, such as vision and reaction time. Also, any crashes occurring at higher and higher speeds result in greater and greater structural damage to the auto, and tragic consequences for the occupants. In fact, the probability of a fatality in a crash roughly doubles as travelling speed increases from 45 to 60 mph, and doubles again as speeds go to 70 mph.

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*Absolute Fatalities indicate the total number of fatalities reported.

b. Why Not Raise the Speed Limit to 60 mph?

We've seen that 55 mph has been proven to be a relatively safe and economical speed. We've also seen that higher speeds, such as 70 and 80 mph are considerably more dangerous. But what about 60 mph? Can a 5 mph increase in speed have that great an impact on accident and fatality rates? Besides, aren't most people driving at 60 mph anyway? Let's examine these two questions in more depth. First, would raising the speed limit affect fatality rates, and next, are people complying with the 55 mph speed limit?

c. Effects of Raising the National Speed Limit from 55 mph to 60 mph

One study which clearly demonstrates the possible effects of raising the national speed limit was conducted by NHTSA in 1977. The study estimates the increase in the number of motor vehicle accidents, injuries, and fatalities that would result from an increase in the national speed limit to 60 mph. It was determined that raising the speed limit would have a relatively small effect on the number of accidents and injuries (approximately 1% and 2% respectively). However, a 9% increase in the number of fatalities was expected. This means that a 5 mph increase in speed limit would not significantly change the frequency of accidents, but rather the severity of these accidents.

The projected 9% fatality increase mentioned above translates into about 3,500 lives. This figure comes close to the total number of lives reported saved in 1974 and 1975 due to the 55 mph speed limit. In effect, raising the speed limit to 60 mph could offset most of the safety benefits achieved by the 55 mph speed limit.

3. State and Local Speed Limits

The preceding discussion has emphasized the National Speed Limit - 55 mph - which, of course, applies essentially to the Interstate Highway system and to major state highways. That is to say, we have been talking more about state agency enforcement than we have about enforcement by municipal or other local agencies. The reader can certainly ask: does the enforcement of local speed limits (state, county or municipal) have a benefit or payoff comparable to that realized from enforcement of the higher speed limits? The answer is an unqualified "yes".

Basically the reason for that answer is that at any speed, the factors we talked about earlier - driver reaction time, total stopping time, the severity of an accident, the likelihood of a fatal accident and fuel usage - are operative. The faster a car is driven, the worse each of these factors becomes: for example, the vehicle travels farther during the driver's reaction time and more fuel is used than at lower speeds. Obviously, the changes in these factors between, say, 30 mph and 40 mph are not as dramatic as the changes between 55 mph and 65 mph. Never the less, the changes do occur and effective speed enforcement will help reduce the impact on accident frequency and severity.

There is another, perhaps even more important reason for stressing enforcement of local speed limits. That reason is simply that a very substantial number of fatal accidents now occur under local jurisdictions. There is an opportunity to affect accident severity and frequency in these areas that is at least as great as the opportunity at the state level. Consider the following table:

TABLE 2-I

Percent of Fatal Accidents by Type of Roadway (1978)

Interstate	Other U.S. Route	Other State Route	County Road	Local Street	Other
8.8	16.0	32.4	15.9	19.7	7.2

The last three locations are already under local jurisdiction and together account for over 42% of all fatals. Since in many situations parts of state (including U.S. Route) highways are under local jurisdiction, we believe that it can be said that half of all fatals do come under local enforcement. That fact alone argues eloquently for improved effectiveness of local speed enforcement.

BASIC PRINCIPLES OF RADAR SPEED ENFORCEMENT

1. Fundamental Concept

The word "RADAR" is an acronym; it's an abbreviation of the phrase RAdio Detection And Ranging. RADAR was developed during during World War II and used primarily for detecting the approach enemy aircraft and ships. After the military dropped its top secret classification, in 1948, RADAR saw its first civilian use when traffic engineers utilized it to determine average highway speeds. Then, in the early 1950's, police agencies began to employ RADAR devices to enforce speed laws.

The early police RADAR units were big, bulky, and tempermental. They were of the stationary type; mainly being mounted on tripods alongside the roadway, and required considerable time just to set up.

During the last 30 years, RADAR units have evolved from the first crude, bulky units to the compact and highly mobile devices that are used today. The technology developed in the space program and the development of the micro-processor in the computer industry have been the major contributing factors in the development of todays police RADAR.

Police RADAR provides a speed reading on a detected target, but not the range of the target. Police RADAR is one type of a small family of RADARs that provides no range information.

For the sake of explanantion we will consider the modular RADAR unit; it consists of two elements, the antenna head and the counting unit. The antenna head sends out and receives the reflected radio waves. The counting unit, or box, receives the signal from the antenna, then filters it and converts the signal into miles per hour which appears in the visual display window.

Radio energy, whether transmitted or reflected, always travels at 186,000 miles per second. You probably recognize that number as the speed of light; both radio energy and and light energy travel at the same speed. The speed of radio energy is, therefore, a "constant" in all computations performed by any RADAR set.

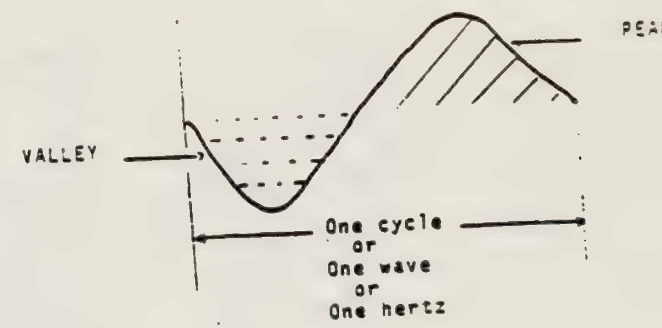
Another characteristic of radio energy is that the frequency (the number of cycles per second) changes when reflected from a moving target. This change or shift in frequency is known as the "Doppler" shift.

2. The Wave Concept

To examine how the reflected signals are changed by relative motion requires an understanding of the wave nature of those signals. If one end of a rope is tied to a pole and the other end is given a sharp upward "snap" you will observe a wave travel down the rope toward the pole: a distinct peak followed by a distinct valley. If you snap the rope steadily you will generate a steady stream of waves, a continuing series of peaks and valleys.

This wave motion also exists in sound, light, and in radio; any sound or beam of light can be described in terms of waves;. the frequency will be different. All radio waves have three distinguishable charecteristics:

1. The signal speed (a.k.a. the speed of propagation) Every RADAR signal travels at the speed of light (186,000 miles per second or 30 billion centimeters per second) This is a CONSTANT.
2. The wave length (a variable) The physical distance or length from the beginning of the peak to the end of the valley. Most signals have wave lengths of about 3 centimeters (approx. 1-1/5 in.) See illustration (not to scale)



3. The frequency (variable) The number of waves transmitted in one second of time - police RADAR signals have frequencies of more than 10,000,000,000 waves per second, ten billion hertz is also referred to as ten gigahertz

Police RADAR generally operates on one of two principle frequencies X-BAND, at 10.525 gigahertz and K-BAND, at 24.150 gigahertz.

Frequency times the wave length will ALWAYS equal the speed of light:

X-BAND — Frequency times wave length - 10.525 X 3 centimeters equals 30 billion cm per second = 186,000 miles per sec

K BAND — 24.150 X 1.25 cm = 30 billion cm = 186,000 m.p.s.

Since that fundamental relationship is true for every RADAR signal, we now can see what must happen whenever a RADAR signal is changed: When a change occurs, the signal's Speed Stays the Same, but its wave Length and Frequency BOTH Change.

3. The Doppler Principle

Christian Johann Doppler, an Austrian physicist, is credited with having discovered the fact that relative motion causes a signal's frequecny to change. He discovered this basic scientific fact by studying sound waves, but it was later found that the principle applies to all kinds of wave motions, including light waves and radio waves.

Practically everyone has, at one time or another, heard how the Doppler principle affects sound waves. If you have ever stood near the railroad tracks when a train has approached, you probably noticed that its whistle made a high pitched sound. In discussing sound waves, pitch is another word for frequency. Then, as the train passed, you noticed an immediate drop in pitch. What happened was the frequency of the train's sound was changed due to relative motion: as the train approached, you heard a high pitched sound; as soon as it passed and started to move away from you, the sound changed to a lower frequency.

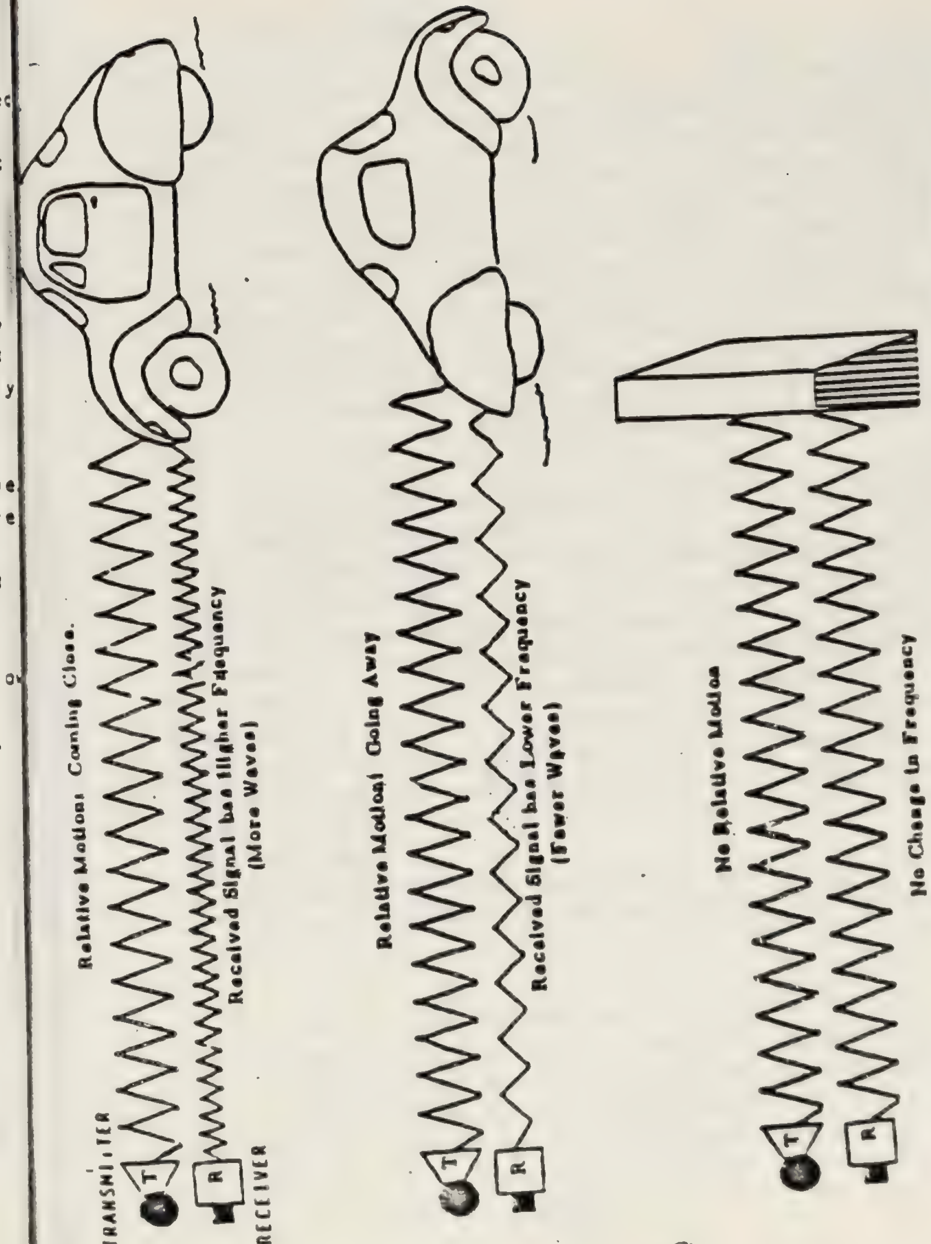
We can express the Doppler Principle in RADAR terms as follows:

a. Whenever there is relative motion between a RADAR and a solid object, the frequency of the transmitted signal will be different from that of the reflected signal.

b. If the relative motion is bringing the RADAR and the object closer together, the reflected signal will have a higher frequency than the transmitted signal.

c. If the realtive motion is taking the RADAR and the object farther apart, the reflected signal will have a lower frequency than the transmitted signal.

d. The speed of the relative motion determines exactly how much higher or lower the reflected signal's frequency will be. See Figure 3-1.



(Note: This drawing shows the transmitter and receiver functions separately only to simplify the illustration. The actual equipment consists of a single unit--a "transceiver.")

Figure 3-1 Basic [illegible] Principle

If the microwave beam projected from the RADAR antenna strikes an object that is moving toward the RADAR, the reflected microwave signal is "compressed" - the frequency is shifted to a higher frequency. The amount of shift is directly proportional to the speed of the approaching object. An X-Band RADAR, operating at 10.525 gigahertz, experiences a shift of 31.389 cycles per second for every mile per hour that a vehicle is travelling.

If the beam is reflected off a target going away from the antenna, the reflected beam is "lengthened", that is, the beam is "stretched" to a lower frequency. The shift rate is the same at 31.389 cycles per second for each mile per hour that the vehicle is travelling whether it is moving towards or away from the RADAR.(for X-BAND RADAR)

For example, a target vehicle approaches the X-BAND RADAR at 70 miles per hour. The beam strikes the oncoming car at 10,525,000,000 cycles per second and is reflected at 10,525,002,197 c.p.s. (31.389 X 70 = 2,197). The circuitry in the counting unit monitors this return signal and translates the shift into miles per hour.(The frequency shift experienced by a K-BAND RADAR signal is 72.0234 c.p.s. per m.p.h.)

When we apply the Doppler Principle, all that we can do is compare the transmitted and reflected signals and determine the speed of relative motion. We cannot tell whether the object is moving , or the RADAR is moving, or both. All we can tell is how fast they are moving relative to one another. The RADAR instrument only indicates how fast the distance between them is changing.

In order to become a competent RADAR operator, it is not absolutely necessary that you understand completely how or why the Doppler Principle works. Is is sufficient that you are aware that there is a valid scientific basis for RADAR speed measurement.

4. Angular Effect

If we have a stationary RADAR, any relative motion must be caused by vehicular movement. If the target vehicle is moving directly toward or away from the RADAR, then the speed of the relative motion will be exactly equal to the vehicle's true speed. But usually we do not have that situation. For obvious safety reasons, we usually set up a stationary RADAR alongside a roadway, at least a short distance off the travelled portion of the road surface.Then, cars travelling along the roadway will not be heading directly towards or away from us, but will pass by us at a safe margin. Whenever we have that situation, what we have done is to create some angle between vehicle's direction of motion and the RADAR's position. See Figure 3-2.

The angular effect, sometimes called the cosine effect, can be explained as follows:

A stationary RADAR will measure the true speed of an object only when that object is moving directly towards or away from the RADAR. Under any other circumstance the angular effect will cause the stationary speed measurement to be lower than the object's true speed. The amount of difference between the measured speed and true speed depends upon the ANGLE, between the object's motion and the RADAR's position: the larger the angle, the lower the measured speed. This effect always works to the motorist's advantage when the RADAR is operated in the stationary mode.

In moving RADAR the angle effect results in a lower patrol speed, therefore, increasing the indicated speed of the target.

In order to minimize the angular effect of stationary RADAR, we must keep the angle as small as possible. We must set up as close to the travelled portion of the roadway as possible; so as not to create a safety hazard either to ourselves, or to others. Even then, the width of the angle will depend on how far away the target vehicle is, when clocked; as the target gets closer, the greater the angle. See Figures 3a & 3b.

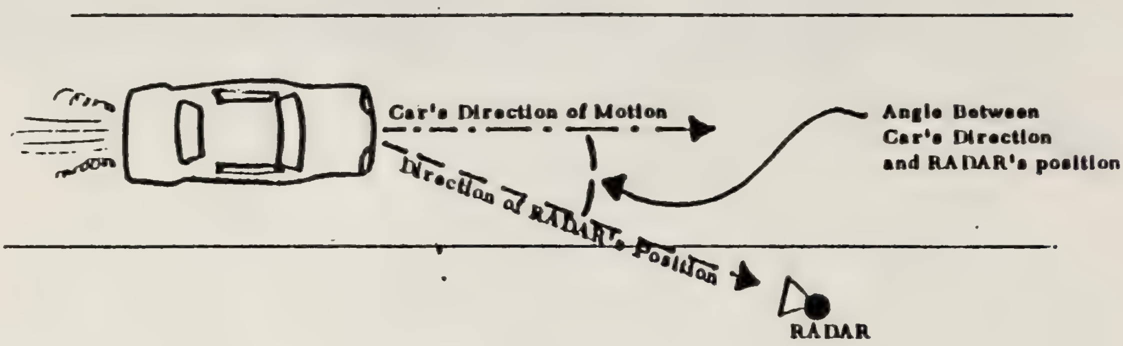


Figure 3-2 Stationary RADAR Set-Up: Angular Effect

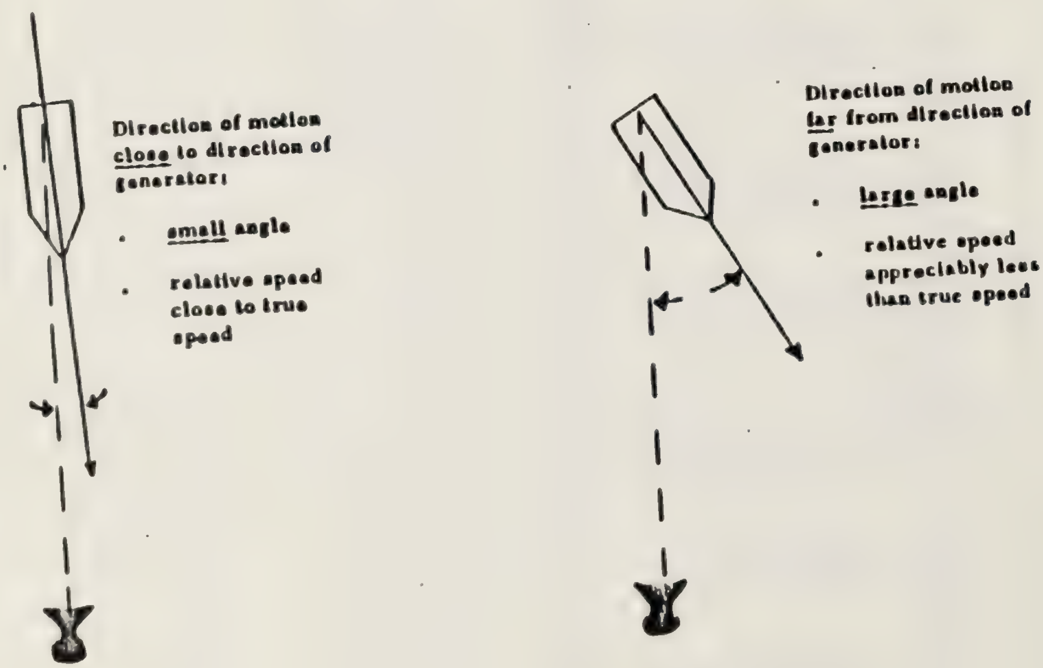


Figure 3-3a Relationship between Angle and Relative Speed

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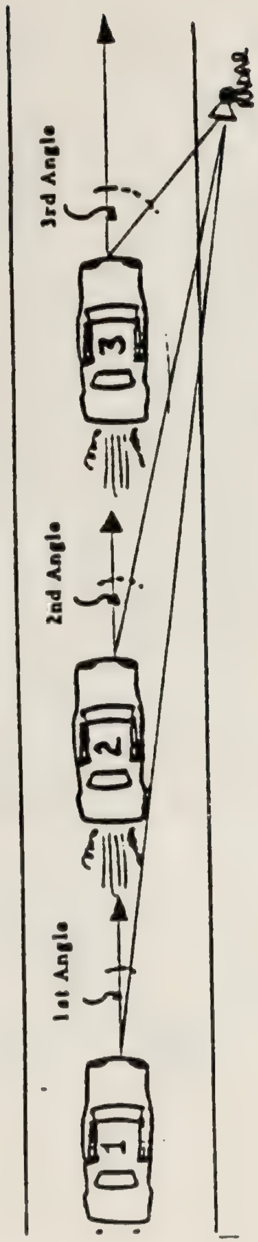


Figure 3- 3h Effect of Vehicle's Position on Measurement Angle.

Table 3-L

True Speed as Affected by Angle of RADAR

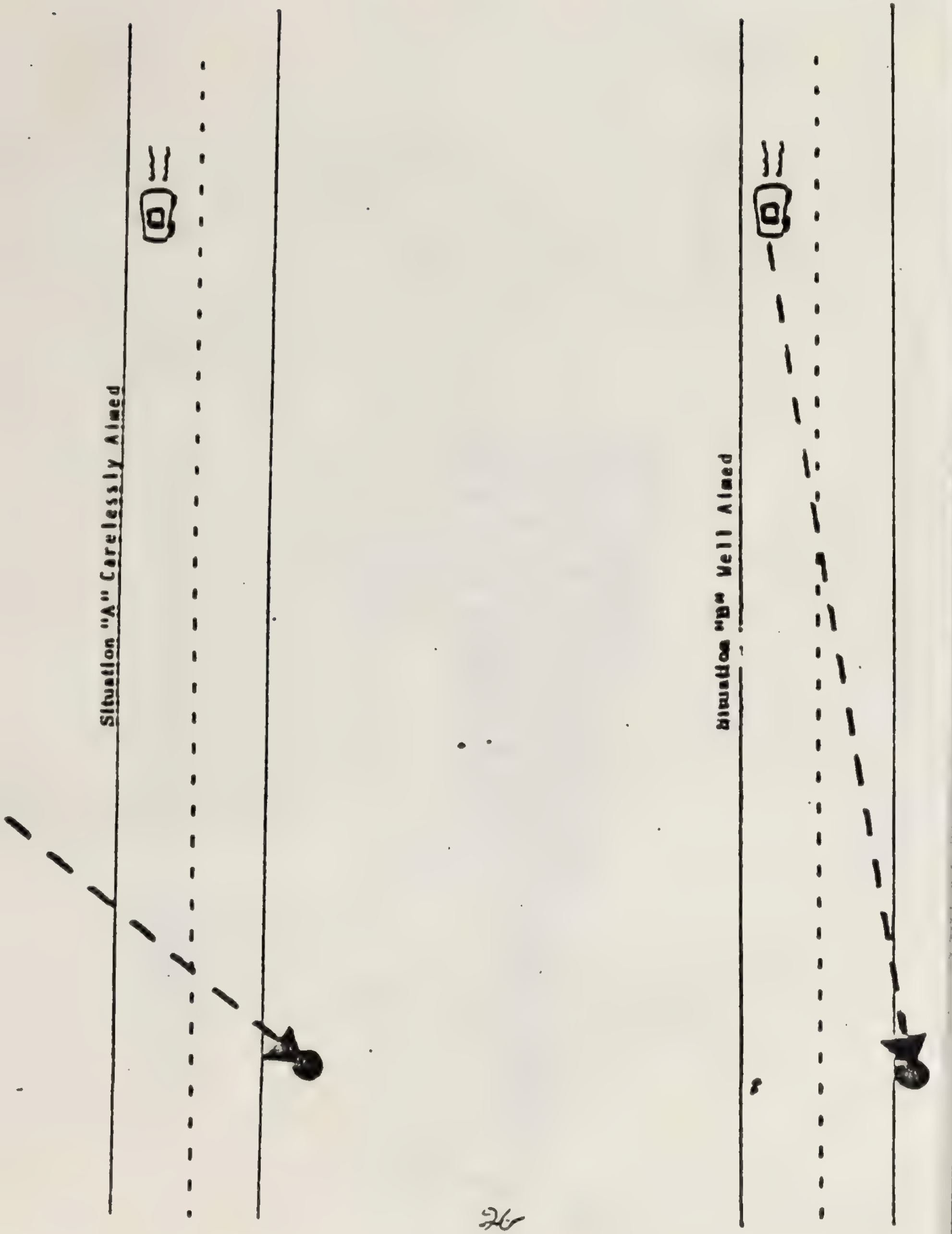
Angle (Degrees)	True Speed: 30 MPH	40 MPH	50 MPH	55 MPH	60 MPH	70 MPH
	Measured Speed					
0°	30	40	50	55	60	70
1°	29.99	39.99	49.99	54.99	59.99	69.99
3°	29.96	39.94	49.93	54.92	59.92	69.90
5°	29.89	39.85	49.81	54.79	59.77	69.73
10°	29.54	39.39	49.24	54.16	59.09	68.94
15°	28.98	38.64	48.30	53.12	57.95	67.61
20°	28.19	37.59	46.99	51.68	56.38	65.78
30°	25.98	34.64	43.30	47.63	51.96	60.62
45°	21.21	28.28	35.36	38.89	42.43	49.50
60°	15.00	20.00	25.00	27.50	30.00	35.00

EXAMPLE: **If an automobile travelling 70 miles-per-hour moves in a directio that makes an angle of 15° with the RADAR beam, the RADAR speed measurement will be 67.61 miles-per-hour. (See circled entry in the above Table).**

Some police RADAR operators occasionally set up an appreciab distance from the roadway, in order to conduct covert surveillance. You should be aware that this will magnify the impact of the angular effect. The result may be that some speeders will escape apprehension because your RADAR speed measurements are lower than their true speeds.

How we aim or point the RADAR antenna head will have an impact on the magnitude of the angular effect. In the upper picture of Figure 3-4(Situation A), the RADAR has been carelessly aimed; it is pointing across the roadway, rather than down the road. The result might be that we would not obtain a speed reading until the target vehicle is quite close, and then the angular effect is fairly large

In Situation"B", the RADAR is well aimed; the speed reading will be accurate and the angle factor is low.



5. Target Selectivity and Sensitivity

The RADAR transmitter does not send out energy in all directions. Instead, the antenna head focuses most of its energy into a cone-shaped beam. This RADAR beam is very similar to the beam of light that is sent out by a searchlight. However, within the cone is a cigar-shaped beam; most of the energy in the RADAR beam is concentrated into that central core. Figure 3-5 gives a rough sketch of the shape of a RADAR beam. The side lobes are insignificant in power and are caused by minor imperfections in the antenna head. Within the central core of the beam, the concentration of beam energy, or beam strength, drops off the further we go from the transmitter. If a target is far from the transmitter, it will be struck by little energy; therefore, it will reflect relatively little energy back toward the RADAR receiver. If a target is close to the transmitter, and directly in the path of the maximum beam strength, it will receive and reflect more energy.

Not all objects reflect RADAR energy equally well. Metal objects, like cars and trucks, reflect RADAR beams quit well, as do objects made of concrete,stone, etc. glass and plastic objects allow most of the beam to pass right through them with little reflection; just as beams of light pass through. The end result is: the amount of energy reflected back from an object depends upon what the object is; its size and mass.

Figure 3-6 shows three vehicles travelling in adjacent lanes towards the RADAR. The motorcycle is the closest; however, it is the smallest and only a small amount of energy will be reflected back. The next vehicle, a regular size passenger car, will be receiving less energy per square inch. The passenger car might actually send back a stronger signal because it has more surface space. The third vehicle, a truck, is the farthest away and in the minimum beam strength range; however, it has the most surface area and could cause a speed reading to be indicated. As the vehicles move closer, the relative strength

Variables which differ between different radar sets:
1. Range or sensitivity
2. Beam width

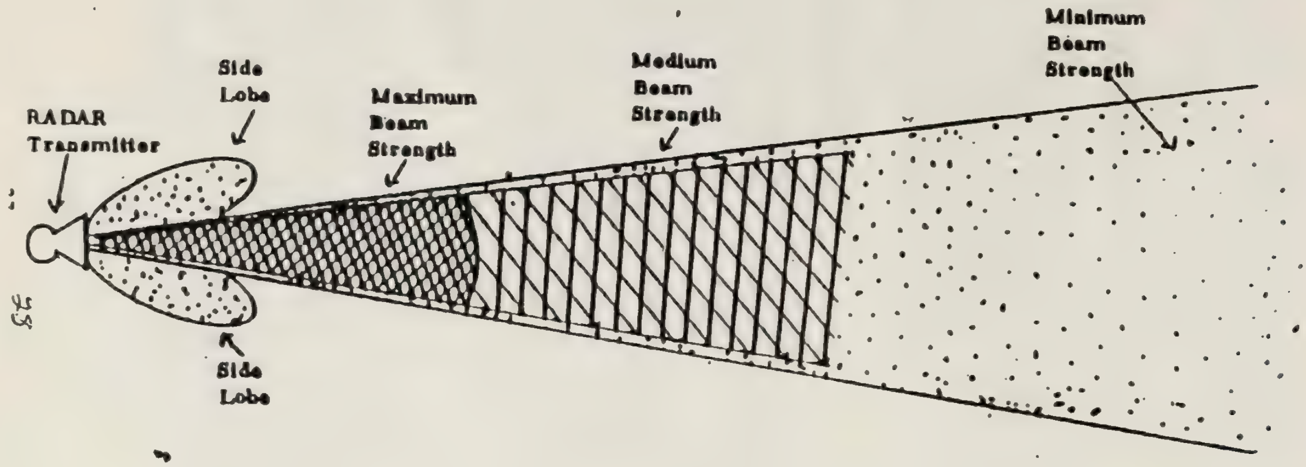


Figure 3-5 Illustration of a Typical RADAR Beam

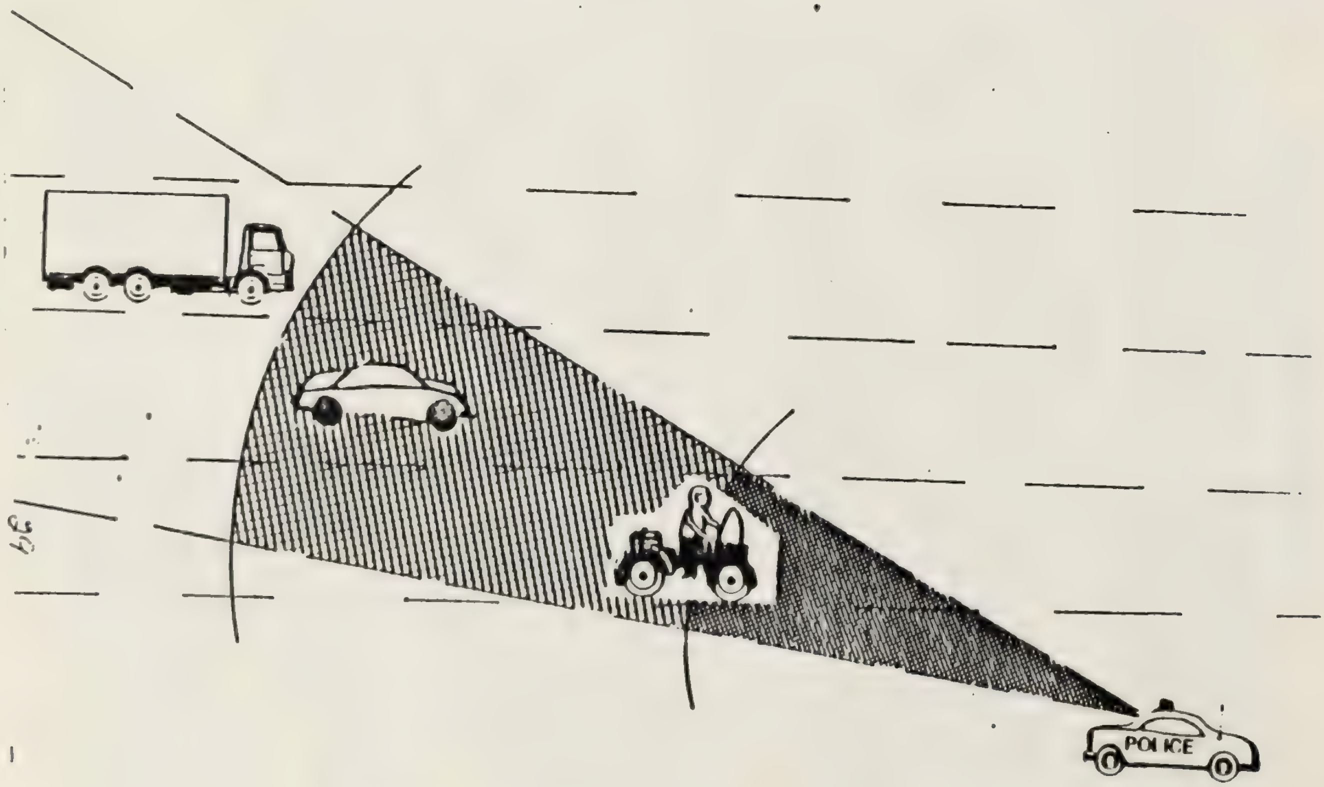


Figure 3-6 RADAR Sensitivity and Selectivity

of their signals might change, and we might observe different speed readings appear as the signals change. The RADAR can not select a particular vehicle to clock in a group; it can only respond to the strongest reflected signal.

6. RANGE CONTROL ADJUSTMENT

The range control adjustment determines only the sensitivity of the receiver; it acts like a squelch control on a radio.You cannot attempt to defeat RADAR detectors by reducing your range because the power of the beam remains constant regardless of the range control setting. It should be mentioned that all RADAR devices are not equipped with range control knobs.

7. AUTOMATIC LOCKING FEATURE

The idea behind the automatic locking feature is to preserve the evidence so that the RADAR operator doesn't have to try to remember what the reading was; it is not designed to show the violator his speed. In fact, it is recommended that the locking feature should NOT be used, at all. Once the speed locks in the operator cannot observe the switching that occurs as each vehicle passes out of the beam; the "target history" will assist the operator to identify the proper violator when there may be selectivity problems.

8. AUDIO DOPPLER

Many RADAR instruments have a feature that will allow you to use your sense of hearing to supplement your visual observations, and help to eliminate selectivity problems. The feature is called audio Doppler or audio tracking. You can hear the sound of the reflected RADAR wave. A high pitched sound indicates a fast moving target; a low pitched sound means a slower moving target. With practice, you can even distinguish whether a vehicle is coming at you or going away.

9. INTERFERENCE, JAMMING, AND DETECTION

Interference encompasses a wide range of natural and man-made phenomena that affect either the transmitted or reflected RADAR beams. For the purposes of this manual we are talking about something which accidently affects the RADAR.

a. Natural Interference

You might observe a target vehicle headed toward you, monitor its speed, then observe the speed measurement simply disappear for a few seconds, and then suddenly reappear. All of this happens while the vehicle remains in sight. "Multi-path beam cancellation" results when a phase inversion occurs in the transmitted signal which cancels the energy reflected from the target vehicle. During this brief period no signal is received and the RADAR display blanks from the readout.

b. Man Made Interference

Moving objects, such as rotating signs, because they are moving will reflect a RADAR beam and give you a speed reading. The rotating movement of fan blades, such as those found on buildings, i.e. exhaust fans and air conditioners, can act as false targets.If the RADAR beam is transmitted through the windshield the patrol car's own defroster or air conditioner fan can cause ghost readings; that is, a speed reading when there is no target vehicle present.

The news media "blitz" which occurred in Dade County, Florida in 1979 brought many "inaccuracies" to the public. What was not so widely reported, was that there were valid reasons for apparantly clocking trees at 85 mph.

A CB radio located in the same vehicle as the RADAR, or in close proximity, very close, when keyed can cause "noise" in the radio frequency that Radar operates on and give high readings; whether pointed at a tree or at the ground. It is not likely that someone talking on a CB while driving down

a highway could mistakenly be apprehended for speeding simply because the surface of his vehicle while travelling would reflect more waves than those of his CB radio. The RADAR will always give the reading of the stronger signal.

In Dade County, they also had a 28 mph house; the RADAR was aimed through the front windshield, some of the beam was deflected downward. The speed on the house was actually the speed of the fan on the defroster motor

The scanning effect may occur if the stationary unit, as in a hand held.RADAR, is swung rapidly past some stationary mass, as a parked car or a brick wall and then taking a reading on a target vehicle. The swinging creates relative motion which induces a change between the transmitted and received signal.

The panning effect happens only with two piece RADAR units; the antenna head and the counting unit are two separate pieces. If the antenna head is pointed at the counting unit, an erroneous speed measurement may appear on the readout. Electronic feedback between the two units cause the reading.

B. JAMMING

This is not a widespread problem since jamming devices tend to be expensive and somewhat complicated. Still, you might encounter one. All radio transmitters must be registered with the Federal Communications Commission (FCC) A jammer would be a radio transmitter which operates on the same frequency as police RADAR. There is one which is currently on the market, illegal, of course, which has two frequencies: one which will indicate to a police RADAR that you are travelling at 55 mph on the highway, no matter how fast or slow you're travelling, and one frequency for urban driving, which always indicates travel at 25 mph. Whether a transmitter was licensed or not, it would still be in violation of FCC regulations if it was used to jam police RAdar. If you happened to come across one, operator license and registration information should be taken and the FCC field office notified immediately.

Other attempts at jamming range from the ridiculous to the absurd; many are based on pseudo-scientific superstitions and really have no affect on RADAR what-so-ever:

Paint aluminum stripes or hang metal strips on the outer surface of the front of the vehicle(If anything, this would reflect more RADAR and make it easier to get a speed measurement)

Hanging chains on the underside of the vehicle ?

Hiding small metal objects or strips of metal foil inside of the hubcaps (RADAR does not penetrate metal and if it did this would have no bearing on a speed reading)

Honking of a horn, either in short beeps or long bursts (Theoretically, the vibrating diaphram of the horn could modulate a RADAR signal; however, since the horn is under the hood, these vibrations won't be detected.)

C. DETECTION

Obtaining advance warning of the presence of police RADAR assists the speed violators to avoid apprehension. The oldest and most common method relies on co-operation among the violators; flashing thier headlights to warn one another of the RADAR's presence.

A more modern method is to warn each other through the use of CB radios. The "Good buddies" keep a close watch on "Mr Smokey" and his "picture taker".

A good principle of selective enforcement can be applied by moving up and down a stretch of roadway, periodically. Don't run RADAR in the same place all the time. By keeping the public guessing as to where you are, you can create a deterrent effect over a larger area; not just where you are set up.

The most modern means of detection of police RADAR by the public is the radar detector. The mystique of the detector can easily be dispelled; it is nothing more than a radio receiver which operates on the same frequency as police RADAR. As you know, the transmitted beam has strong and weak areas. once transmitted, the weak portions of the beam go on into infinity. A radio receiver, such as a detector, can pick up the weak signals, light a warning light, or even sound an alarm.

The most effective means which the police have to defeat the detector is the "optional" Anti-detector Switch. The switch is used with the modular or two piece RADAR. The operator observes traffic; the RADAR is ON, but it is only "idling", that is, the beam is not being transmitted. When the operator observes a violator, he pushes the switch and the beam goes out instantaneously; at the speed of light. Even if the violator has a detector, it is too late; he's already been clocked.

10. PRINCIPLES OF MOVING RADAR

The moving RADAR operates much the same way as the stationary RADAR; however, the moving RADAR's receiver is able to detect two reflected signals simultaneously; one from the ground and the other from the target vehicle. The signal coming back from the target vehicle has undergone a change in frequency change known as a "high Doppler shift"; caused by the fast closing motion between the target vehicle and the patrol car. The signal coming back from the ground has undergone a "low Doppler shift"; a lesser frequency shift caused by the patrol car's own speed. The moving RADAR then computes the difference between the high and low Doppler shifts, and translates that difference into a target vehicle speed measurement. Figure 3-7 is a simplified illustration of the principles of moving RADAR.

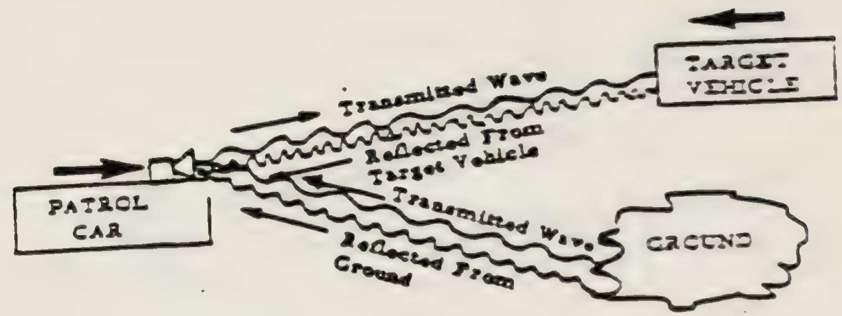


Figure 3- 7 Principles of Moving RADAR Speed Measurement

a. Angular Effect on Moving RADAR

The angular effect might cause a moving RADAR to produce a target speed measurement that is higher that the target's true speed. It will be helpful to think of the following formula to understand how moving radar operates:

TARGET SPEED EQUALS CLOSING SPEED MINUS PATROL SPEED

$$TS = CS - PS$$

If we have a low patrol speed measurement, the formula will produce an erroneously high target speed. For example, suppose the target's true speed is 55 mph, and the patrol's true speed is 50 mph. The true closing speed between the two would be 105 mph. Now, suppose the angular effect produces a low patrol speed measurement: instead of 50 mph, suppose the angular effect gives us an apparent patrol speed of only 45 mph. Then, the computer would calculate as follows:

$$TS = CS - PS$$
$$TS = 105 - 45$$
$$TS = 60 \text{ mph}$$

Our target speed result would be 5 mph higher than the target's true speed. Under some circumstances, enforcement action might be taken when there had been no violation. To avoid the possibility of enforcement error we must ALWAYS compare the indicated patrol speed on the readout module with the speedometer reading at the time of a speed violation reading.

b. Patrol Speed Shadowing

The shadowing effect, like the angular effect, can produce a lower than actual patrol speed measurement, and can lead to a higher-than-true target speed calculation. Figure 3-8 illustrates the shadowing effect. Suppose that the RADAR equipped patrol car and the truck are moving in the same direction; the patrol car is moving at 50 mph and the truck is moving at 40 mph.

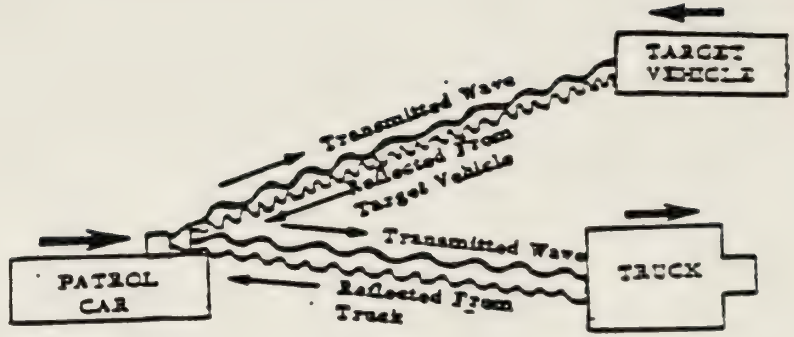


FIGURE 3-8 SHADOWING EFFECT IN MOVING RADAR USE

The speed of the patrol car relative to the truck is 10 mph. The moving RADAR could mistakenly measure the patrol car's speed at 10 mph. In effect, the RADAR would think that the truck is the ground, and this ground happens to be moving at 40 mph.

Meanwhile, the other RADAR beam is striking the target vehicle and undergoing the high Doppler shift. The combined speeds of the target vehicle and the patrol car is 120 mph. Again, the computer swings into action:

TS = CS-PS
TS = 120 - 10
TS = 110 mph

Unfortunately, the computer believes that the patrol speed is only 10 mph and calculates the target speed at 110 mph. Obviously this is a very large deviation from the target's true speed of 70 mph. Even worse, from a legal standpoint, the deviation is not in favor of the target vehicle. This situation does not occur frequentle, but it can occur. Again, by monitoring your patrol speed,as in the angular effect, this problem can be avoided.

c. Batching

The batching effect is caused by slight time lags in the moving RADAR's sensing/computing cycle. The batching effect can lead to either high or low target speeds; depending on whether the patrol car was accelerating rapidly or braking sharply at the time the speed reading was taken. In any case, the batching effect can be avoided by maintaining a relatively steady speed and monitoring your own patrol speed when taking speed measurements.

d. Reflections

It is possible that while operating the RADAR in the

moving mode, that spurious (ghost) readings can appear. These readings are caused by reflections of the beam from stationary objects alongside of the roadway; i.e.billboards, overpasses, etc. Spurious readings should not create a problem; you need only to be aware that such readings can appear under certain conditions and for a very short time.

LEGAL and OPERATIONAL CONSIDERATIONS

1. Requisites for Introduction of Scientific Evidence

It is important to remember at this point that judicial notice extends only to the scientific accuracy of the principle upon which a particular device operates. Judicial notice does not extend to the accuracy or efficiency of any given instrument designed to employ that principle. Once judicial notice has been taken of the principle, it must be obtained for the type of device employing that principle with respect to both accuracy and reliability. And, after the court has accepted a particular device, it is still necessary to establish the qualifications of those who use the device.

2. Fundamental Case Law

a. Judicial Notice

In 1955, the Supreme Court of New Jersey decided a landmark case, State vs. Dantonio. In deciding this case, the court accepted the Doppler principle as having a valid scientific basis. In doing so, the court had extended judicial notice to the RADAR concept; this swept away the artificial formality of the prosecution having to produce expert witnesses to explain the scientific basis of RADAR before the court could hear the circumstances of the complaint.

b. Device Accuracy

The court cannot simply accept every single RADAR device as being totally accurate at all times. Proof must be supplied to demonstrate that a particular device was functioning properly at the time it was used to obtain a speed reading. In doing so the court can reasonably assume that is a particular device were checked for accuracy at various times, through accepted methods, then the readings obtained could be received as accurate and acceptible.

An efficient, convenient, and popular method for testing the accuracy of RADAR units is accomplished through the use of a tuning fork (one or more). The use of the tuning fork was established as an accurate method of testing by the Supreme Court of Connecticut in State vs. Tommanelli.However, the accuracy of the tuning fork may be challenged by the defendant. If no challenge is offered, the accuracy of the tuning fork will stand, as well as the accuracy of any device which was properly tested by that tuning fork.

c. Operator Qualifications

The courts have had little difficulty in outlining the qualifications of a RADAR operator. In Honeycutt vs Commonwealth,the Kentucky Court of Appeals said:

"It is sufficient to qualify the operator that he have such knowledge and training as enables him to properly set up, test, and read the instrument; it is not necessary that he understand the scientific principles or be able to describe the inner workings, a few hours instruction normally should be enough to qualify an operator."

3. Violator Identification

In addition to to the establishment of the speed of the vehicle the officer must be able to prove that a particular speed law was violated, the defendant was the driver, and that the offense occurred on a public way. In cases where RADAR was used to obtain a speed measurement, the officer must also be to identify the violator's vehicle and how he made the determination that the vehicle in question was in fact, the violator's whose speed measurement was obtained.

In dealing with the problem associated with violator (vehicle) identification the courts have outlined the proper precedures to be employed by a RADAR operator. The officer

should estimate the speed of a suspect violator, through visual observation. Once that vehicle has been singled out, then the RADAR can be used to confirm the speed. Provided that the vehicle was out front, by itself, when the speed reading took place, and that it was the closest vehicle to the RADAR, at the time of the alledged violation.

4. CASE PREPARATION and PRESENTATION

When preparing a case for presentation, it may be helpful for the officer to keep these elements in mind:

a. The officer must be able to establish the time, place, and location of the RADAR device, the location of the offending vehicle at the time of the offence, identify the operator of the vehicle, the clocked speed, and the posted or legal speed limit in that area at the time of the violation.

b. The officer must state his qualifications and training.

c. He must establish that the machine was operating normally.

d. He must establish that the machine was tested for accuracy prior to and after its use by the use of a certified tuning fork

e. The officer should identify the vehicle and indicate how and when he made a visual estimate of the violation

f. The officer must establish the tracking history and indicate that the vehicle was out front, by itself, when the speed reading was taken.

g. If moving RADAR was used, the officer must testify that the patrol speed was verified by comparison of the readout against the speedometer, and that the patrol speed was steady.

These elements should be incorporated into a clear, concise account of the incident. See Figure 4-1.

Good morning, your Honor. My name is John E. Good. I am a State Police Officer, currently assigned to the Concord Barracks. As part of my patrol procedures, I run RADAR and monitor traffic speeds. I have successfully completed a course in RADAR training and have a certificate of competency. (Introduce certificate, by handing it to the defence attorney, or the defendant)

On April 1st, 1982 at 10:30AM, (Date & time) I had the RADAR set up on Route 2, Westbound lane, in the Town of Acton. (Location) Route 2, in that area, is a four lane divided highway, posted speed 45 mph. (Description) The speed limit is reduced from 55 mph to 45 mph through that area because of entering and turning traffic at various intersections. In addition, there have been numerous accidents in that area which have been associated with excessive speed. (Reasoning and rationale)

The RADAR set was an MPH, K-35, stationary unit. (Make, model, and type) After assembling the machine, I turned it ON. The first thing I did was to check the Light Test (L/T) Next, I checked the Internal Calibration; it's supposed to give a reading of 64 mph and it did. Then, I used a certified tuning fork and obtained a reading of 50 mph. I was satisfied that the RADAR was operating properly.

I was parked 6-8 feet from the edge of the roadway, in a safe area, where I had an unobstructed view of the Westbound traffic. Route 2, in that area, is a public way.

At approximately 10:40AM, I observed a blue Volkswagen travelling Westbound, in the passing lane, at a high rate of speed. I estimated his speed at 65-70 mph. (Visual observation) The traffic was medium, and, at that time, there were no other vehicles in the vicinity or close proximity. Then, I checked the RADAR reading and observed a speed reading of 66 mph.

At that time, I stepped onto the roadway and signalled the operator to pull over and stop. I approached the vehicle, asked the operator for his license and registration, and then, advised him of the violation. I issued him a citation charging him with speeding. The defendant is seated there. (Identify him) That is the Commonwealth's case, your Honor.

Figure 4-1 Model Testimony Concerning RADAR Speed Measurement

5. INSTRUMENT LICENSING

A RADAR unit is composed of a radio transmitter and a receiver; as such , it must be licensed by the Federal Communications Commission (FCC). RADAR for vehicle speed measurement is classified as a "pushbutton" device and, as such,only requires a station license.Operators of RADAR equipment do not require FCC licenses. The absence of a FCC license should not effect the credibility of a RADAR unit; to operate with out the license is a violation of the FCC regulations.

6. GENERAL OPERATING PROCEDURES

Any location chosen for RADAR operations should have a valid need, a purpose closely related to traffic safety. Examples of places that have a valid need are locations where:

there have been a significant number accidents associated with excessive speed

there have been high incidences of speed violations in the past

there have been significant numbers of complaints by residents or other citizens

there are special speed regulations or other charecteristics which necessitate selective or special enforcement (e.g. school zones, construction sites, etc.)

there are requirements for conducting speed surveys for planning and allocation of enforcement resources..

Safety is another major consideration in RADAR site selection. The purpose for using RADAR is, ultimately, to improve traffic safety. We do not wish to operate RADAR in a

location where our presence will make the safety situation worse than it already was. For stationary operations, we must choose a location where we may set up sufficiently off the roadway so that we do not impede the flow of traffic; the site should also provide sufficient visability so that we can enter the stream of traffic, safely, in order to conduct pursuit. When operating in the moving mode, we must be very conscious about performing U-turns. In either the stationary or the moving mode, we must consider the safety aspects of stopping the speed violator: the road shoulders or other potential stopping places must be broad enough to insure that the traffic flow is not obstructed. Keep in mind that there is no such thing as a routine stop. Always observe all basic safety procedures when approaching a violator; the consequence of carelessness could be your life!

Traffic and roadway conditions should influence our RADAR selection site. The flow of traffic should not be so congested that it will create problems with target selectivity. The area should have sufficient visability to allow us to detect suspected and perform visual speed estimation. Generally, the roadway should not be excessively hilly or curvy so not to obstruct vision. If any type of interference is detected then another location should be chosen.

7. PREPARATION and USE

Basically, RADAR units fall into two categories: one piece and two piece units. A one piece RADAR has both the antenna and counting unit housed in a single component, i.e. hand held unit.

Obviously, a one piece unit requires no assembly. Be sure that the power switch is OFF before plugging it into the power source; this could avoid a power surge that might damage the instrument. Many hand held units are equipped with light tests and internal calibration checks; the light test (L/T) illuminates all of the segments in the readout, usually the number 188 appears.

The internal calibration reading is pre-set at the factory; it will vary from manufacturer to manufacturer. Whatever the reading is fixed at should be the reading obtained; there is no lee-way, it must be exact. The final test of calibration should be conducted by using one or more certified tuning forks.

Tuning Fork Procedures

Tuning forks are not interchangeable between X-Band and K-Band RADAR. Because of the different operating frequencies, you would not get the desired speed reading for calibration purposes. Tuning forks are usually stamped with the type of fork,i.e. X or K-Band, the reading which they should produce, and a serial number. The fork should be checked periodically for accuracy by an expert and he should issue a certificate stating how and when the fork was checked. As was mentioned earlier, the accuracy of a tuning fork can be challenged.

In preparing to conduct a test on a RADAR unit, the antenna head should be pointed upward, or, if you are sitting in a cruiser, it should be pointed in a direction where there is no vehicular movement. Figure 4-2 shows a typical tuning fork. To use a fork, you simply grasp the fork by the handle and strike one of the tynes against a firm surface. The heel of your shoe or the steering wheel is a good surface. Striking the fork against a hard surface, such as metal or concrete, might bend or even break a fork.

After striking the fork, it should be held in front of the antenna head, up to about 3" away; the distance is not critical. But, if the fork is held too far away, it will not register. Figure 4-3 illustrates the recommended method. In order to "pass" the calibration test the the measurement should not differ by plus or minus 1 mph. If the deviation is more than one mph, Do Not use the machine.

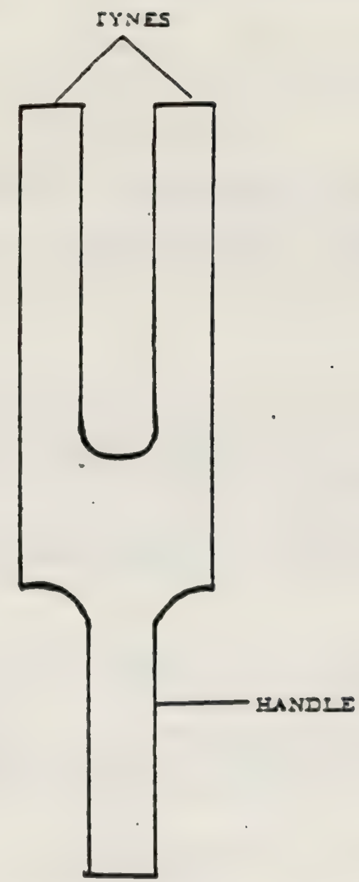


Figure 4-2 Typical RADAR Tuning Fork

Figure 4-3

RADAR SET-UP and CALIBRATION

Follow the A, B, C's:

A = Antennae head (the sender and receiver)

B = Box or counting unit (where you get the visual display)

C = Current or power supply

First: Mount your Antennae head carefully; make sure it is level with the roadway and pointed in the direction of your anticipated target.

Second: Plug the antennae wire into the counting unit, the Box. At this time check the ON - OFF switch; be certain it's OFF.

Third: Last, plug the counting unit into the Current, the power supply.

Calibration:

1. Turn power switch ON
2. Check light test (L/T) 188 should appear in visual display
3. Check internal calibration (pre-set at the factory, no variation!)
4. Conduct external calibration test using one or more certified tuning forks. Fork should read to within 1 M.P.H.

Calibration checks should be conducted hourly, or after each violation where enforcement action was taken; these at the radar operators discretion. However, each time a new location is chosen all calibration tests must be conducted before monitoring traffic.

OPERATION:

DO: Select sites carefully, keep in mind personal safety as well as violator safety after the stop has been made

Observe traffic, estimate speeds and confirm with radar, obtain target history (where the offender vehicle was in proximity to other vehicular traffic and what it was doing,i.e. passing etc.) listen to the audio doppler signal; it can tell you much

DON'T: Point the antennae head at any solid mass within three feet while the unit is ON; the reflected waves can burn out the Oscillator and then it will be useless

DON'T: Rely on the automatic locking feature, if so equipped; it can hinder proper target identification

DON'T: Argue with violators, be firm, be fair, be professional. Advise the violator that he can have his day in court.

TERMINATION OF RADAR OPERATIONS

1. Turn the power switch OFF
2. Grasp the plug firmly and remove it from the power source using a twisting motion.DO NOT grab the cord and snap it from the recepticle; this breaks the strands of wire and can pull the wire from the adapter
3. Un-plug the antennae head, remove it from its mount and place it in the carrying case
4. Put the counting unit away. Be sure that all wires, forks and components are put away carefully.

Commonwealth vs. Kathleen Whynaught.

Middlesex. October 2, 1978 — January 2, 1979

Present: Hennessey, C.J., Quirico, Braucher, Wilkins, & Liacos, JJ.

Hennessey, C.J. The defendant, Kathleen Whynaught, was convicted of speeding pursuant to G. L. c. 90, § 17, after a jury waived trial in the First District Court of Southern Middlesex. Appealing her conviction, she

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argues that the trial judge erroneously admitted readings taken from an untested radar speed measuring device and that the prosecution had a statutory burden, which it failed to meet, to prove excessive operation over a one-quarter mile course. We overrule the defendant's exceptions.

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Although the defendant does not challenge the validity of radar principles or their application to determining speed, we think it appropriate to state here our judicial notice of the radar speedmeter as an accurate and reliable means of measuring velocity. As we said in *Commonwealth* v. *Fatalo*, 346 Mass. 266, 269 (1963), and have repeated more recently in *Commonwealth* v. *Lykus*, 367 Mass. 191, 196 (1975): "Judicial acceptance of a scientific theory or instrument can occur only when it follows a general acceptance by the community of scientists involved. When supported by substantial authority establishing scientific reliability, this court has not hesitated to accept the benefits of science." See also *Commonwealth* v. *Vitello*, 376 Mass. 426, 430-431 (1978). In light of soci-

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ety's widespread use of radar devices, in forms ranging from air-traffic control monitors to homing radars on guided missiles, see M. Skolnick, Introduction to Radar Systems 14-18 (1962), and considering other courts' acceptance of radar, we view the scientific basis of radar as indisputable.[2]

The more substantial question in cases where radar results are offered regards the accuracy of the particular speedmeter at the time the speed measurement was made. While there has been some suggestion to the contrary,[3] most courts have agreed that the admission of radar evidence is conditioned on a demonstration to the court of the accuracy of the radar apparatus. See, e.g., *State* v. *Gerdes*, 291 Minn. 353 (1971); *State* v. *Finkle*, 128 N.J. Super. 199, 207, aff'd 66 N.J. 139 (1974), cert. denied, 423 U.S. 836 (1975); *People* v. *Perlman*, 89 Misc. 2d 973

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